Paper G 4

THE INFLUENCE OF SEASONAL FACTORS ON THE RECOGNITION OF SURFACE LITHOLOGIES FROM ERTS-IMAGERY OF THE WESTERN TRANSVAAL

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ABSTRACT

The value to geological studies of repetitive ERTS-imagery was investigated by comparing two images gathered during different seasons over an area in the western Transvaal Province of the Republic of South Africa.

The first of the two images (1050-07355) was gathered on September 11th., 1972, co-inciding with the end of the dry winter season. The second image (1158-07363) was gathered in the middle of the summer rainfall season on December 28th., 1972.

A comparison of the two images reveals striking differences in the amount of recognizable geological detail. The most pronounced difference is the marked enhancement on the December image of tonal variations associated with individual surface lithologies. This contrast in tonal values is evident in all four spectral bands, though particular bands emphasize individual lithologies more clearly than others. Basic igneous rocks of the Bushveld Complex, for instance, are most clearly defined on bands 6 and 7, while certain areas underlain by granite are distinguishable only on band 4.

Tonal variations on the September image permit recognition of the major lithological units to a degree which is slightly inferior to that displayed by a 1:1 000 000 scale geological map. The very marked tonal differences displayed by the December image, however, permit recognition of detailed lithological units compatible with published geological maps at 1:250 000 scale. In addition, this image reveals the presence of distinct stratigraphic subdivisions within the previously undifferentiated Dolomite Series of the Transvaal System.

The differences exhibited by the two images clearly demonstrate the importance of repetitive ERTS coverage in geological investigations, particularly in areas of marked seasonal variations. In the present case variations in soil moisture content and atmospheric haze appear to constitute the most important factors exerting an influence on the tonal characteristic of different surface lithologies and consequently on the ease of recognition of such lithologies. Under different conditions, however, other seasonal factors may be of equal or greater importance.

INTRODUCTION

This report summarizes the results of a comparison of two ERTS-images of the same area under different climatic conditions, allowing a preliminary assessment to be made of the importance of seasonal factors on the ease of recognition of geological features from ERTS imagery.

The images (1050-07355 and 1158-07363) cover a portion of the western Transvaal Province of the Republic of South Africa, centered on a latitude of approximately 26°S and a longitude of 27°E. The area covered by the images has a steppe climate with the annual precipitation averaging from 900 mm in the east to some 650 mm in the west. Precipitation is almost exclusively in the form of showers and violent thunderstorms, and falls mainly during the summer months from October to March.

Physiographically most of the area lies within the Transvaal Highveld region, a flatlying or gently undulating plateau at an altitude of between 1 800 and 2 200 m above sea level. The topography is strongly dependent on the underlying geology with the more resistant rock units frequently forming conspicuous elongated ridges. The Highveld area is covered largely by prairy grasslands, though the ridges frequently support some acacia thronbush and various indigenous and cultivated trees line the local streams. Large areas are devoted to the cultivation of corn.

The northeastern portion of the image forms part of the Transvaal Plateau basin, consisting of an even flat terrain which is only occasionally broken by low inselbergs of rock outcrop. The vegetation consists almost exclusively of Thornbush savanna but a few small areas are under irrigation and devoted to citrus groves, tobacco and wheat farming.

The area is of considerable geological interest as it includes the gold and uranium mines of the central and west Rand, the platinum and chrome mines of the Bushveld Complex, the Lichtenburg diamond fields, the Marico lead/zinc deposits, as well as numerous other mineral occurrences. Intense geological investigation has been in progress over the last 90 odd years following the discovery of gold in 1886, and the area has been repeatedly mapped both by mining companies and the Geological Survey.

ERTS DATA AND ANALYSIS

The two images compared are 1158-07363 gathered on the 28th of December, 1972 and 1050-07355 gathered on September 11th., 1972. Both images are completely free of cloud cover. All four spectral bands on image 1050-07355 are rated "G" but definition in all four bands on 1058-07363 is poor and all were rated "P".

A detailed comparison of the geological information contained in the two images was based on "conventional" false colour composite prints of spectral bands 4, 5 and 7, enlarged to a scale of 1:500 000. In addition to the detailed comparison between the false colour composite prints, a more rapid comparison was made between black and white paper prints of all four spectral bands of the two images at 1:500 000 scale.

Interpretation of the geological information on the images centered mainly on the recognition and accurate delineation of surface lithologies. Structural features such as lineaments fracture patterns, and faults were given only scant attention.

REGIONAL GEOLOGY

Figure 1 illustrates the regional geology of the area covered by the images.

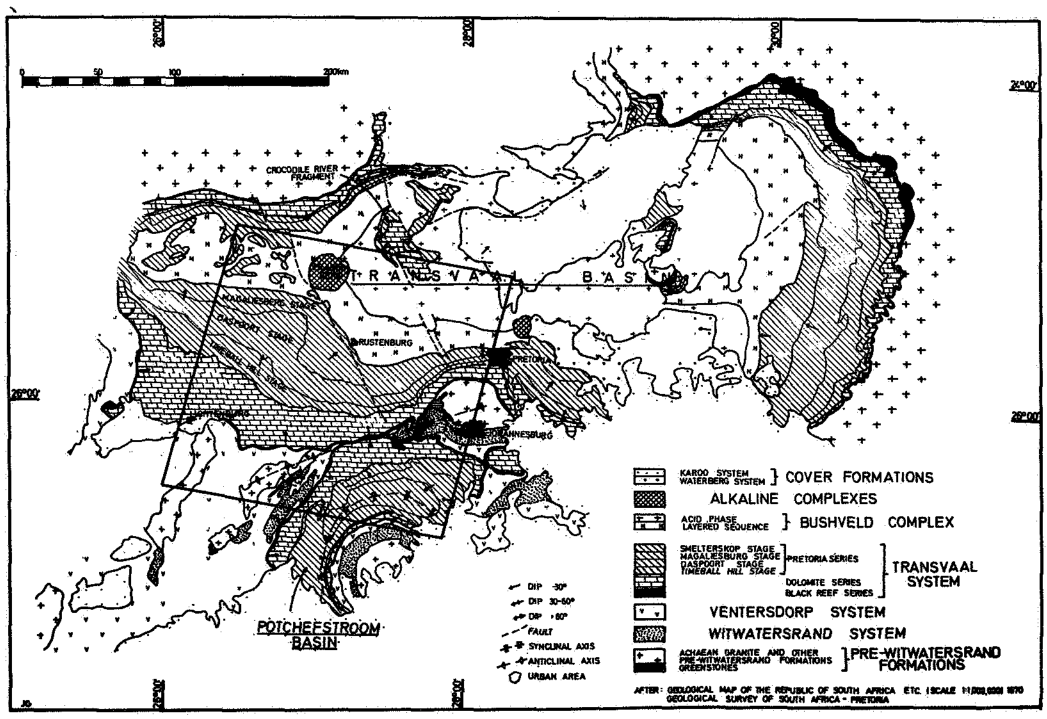

FIG. 1 : Regional geology of part of the Transvaal Province showing the approximate area covered by ERTS-images 1050-07355 and 1158-07363

Most of the area is underlain by rocks belonging to the Transvaal System of late Proterozoic age, consisting of a very thin basal clastic unit (Black Reef Series) overlain by a 1 700 m sequence of massive dolomitic limestone (Dolomite Series), which is in turn overlain by a thick sequence of alternating quartzites and shales with occasional volcanic horizons, (Pretoria Series). Intrusive diabase sills become abundant near the top of the Pretoria Series. The rocks of the Transvaal System have been folded into two synclinal basins, portions of both being represented on the imagery. The northern 2/3 of the images cover the south western portion of the Transvaal basin, characterized by regular structure and shallow dips. The south eastern corner of the images includes a portion of the curved Potchefstroom basin of more complex structure and steeper dips.

The two major basins of the Transvaal System are separated by a major N.E.-trending anticlinal axis along which older rocks of Archaean and Proterozoic age are exposed, the former consisting predominantly of granite with a few scattered occurrences of greenstones. Proterozoic rocks are represented by the Witwatersrand and Ventersdorp Systems, the former sequence consisting largely of quartzites with occasional interbedded shales while the latter comprizes andesitic volcanics with interbedded sediments.

The centre of the Transvaal Basin is occupied by the Bushveld Igneous Complex comprizing the Layered Sequence of basic igneous rocks and the Bushveld Granite consisting of granitic material. The structure of this area is very regular and dips are shallow. West of the Pilansberg, however, the structure is more complex and numerous outcrops of quartzitic floor rocks protrude the basic rocks. The Pilansberg Complex, a circular ring structure made up of a variety of alkaline rocks, intrudes the Bushveld Complex at the northern extremity of the images. Throughout the area small scattered patches of flat-lying and deeply weathered Karroo sediments (tillite, sandstone and shale) occur. Locally surficial deposits of alluvium, surface limestone, windblown sand and scree may obscure bedrock geology. Intrusive rock types include diabase sills in the Pretoria Series, alkaline dykes related to the Pilansberg Complex, and numerous post-Karroo dolerite dykes and sills.

Outcrop conditions are poor and most of the western Transvaal is covered by residual soil. The only units which form significant outcrops are the quartzites of the Witwatersrand and Transvaal Systems, the Pilansberg and occasional inselbergs within the Bushveld Complex.

ERTS-1 IMAGE 1050-07355

This image (fig. 2) was gathered on September 11, 1972 at the end of the dry winter season. At this time of the year the area was largely covered by "khaki-coloured" dry grass with all indigenous vegetation being virtually leafless and the cornfields lying fallow. The false colour composite image of bands 4, 5 and 7 shows a relatively uniform predominantly light brown colour tone. The most distinctive tonal variations are related to areas of dense vegetation along stream channels and areas of wheat agriculture and orange groves. Areas of recent burning are marked by very dark colour tones. Slight tonal variations are associated with certain surface lithologies allowing recognition of the major geological units to a degree roughly comparable to that shown on published 1:1 000 000 scale maps. (Figs. 1 and 4).

The distribution of the Transvaal System is readily recognized and some individual lithological units can be distinguished, particularly in the central portion of the image where the structure is regular. The Magaliesberg quartzite is very evident, primarily due to a shadow effect. Shale bands are characterized by light colour tones though becoming more purple near the top of the sequence. The Dolomite shows a uniform darker tone with particularly the basal zone, immediately above the Black Reef being readily distinguishable. Towards the eastern extremity of the image outcrop areas of dolomite are clearly evident. The pre-Transvaal areas generally show very uniform tonal qualities but textural patterns permit recognition of Witwatersrand rocks. Basic rocks of the Bushveld Complex are readily distinguished by their dark colour tones but a detailed assessment of their distribution is hampered by the effects of numerous areas of burning over their outcrop area. The area underlain by Bushveld granite is characterized by a textureless light colour tone. The Pilansberg Complex can be recognized primarily on the basis of textural characteristics which very clearly accentuate the concentric ring structure. Throughout the image outcrop areas are characterized by uniform darker colour tones. Fracture patterns are clearly visible, as are some of the more prominent dykes.

ERTS-1 IMAGE 1158-07363

The image (fig. 3) was gathered on December 28th., 1972 at the height of the rainy summer season. At this time the area was covered by green grassland with the indigenous vegetation in full leaf. The majority of the cornfields, however, were still largely bare with plants in a very youthfull stage. The false colour composite image of bands 4, 5 and 7 shows very strong tonal variations, the majority of which appear to be directly related to surface lithologies, particularly where shallow dipping rocks of the Transvaal System and the Bushveld Complex are concerned. The major geological units are immediately apparent and can be accurately delineated. (Fig. 4).

Areas underlain by Archean Granite in the eastern portion of the image are characterized by a mottled reddish colour tone, and show a uniform textural pattern. The slightly darker tone associated

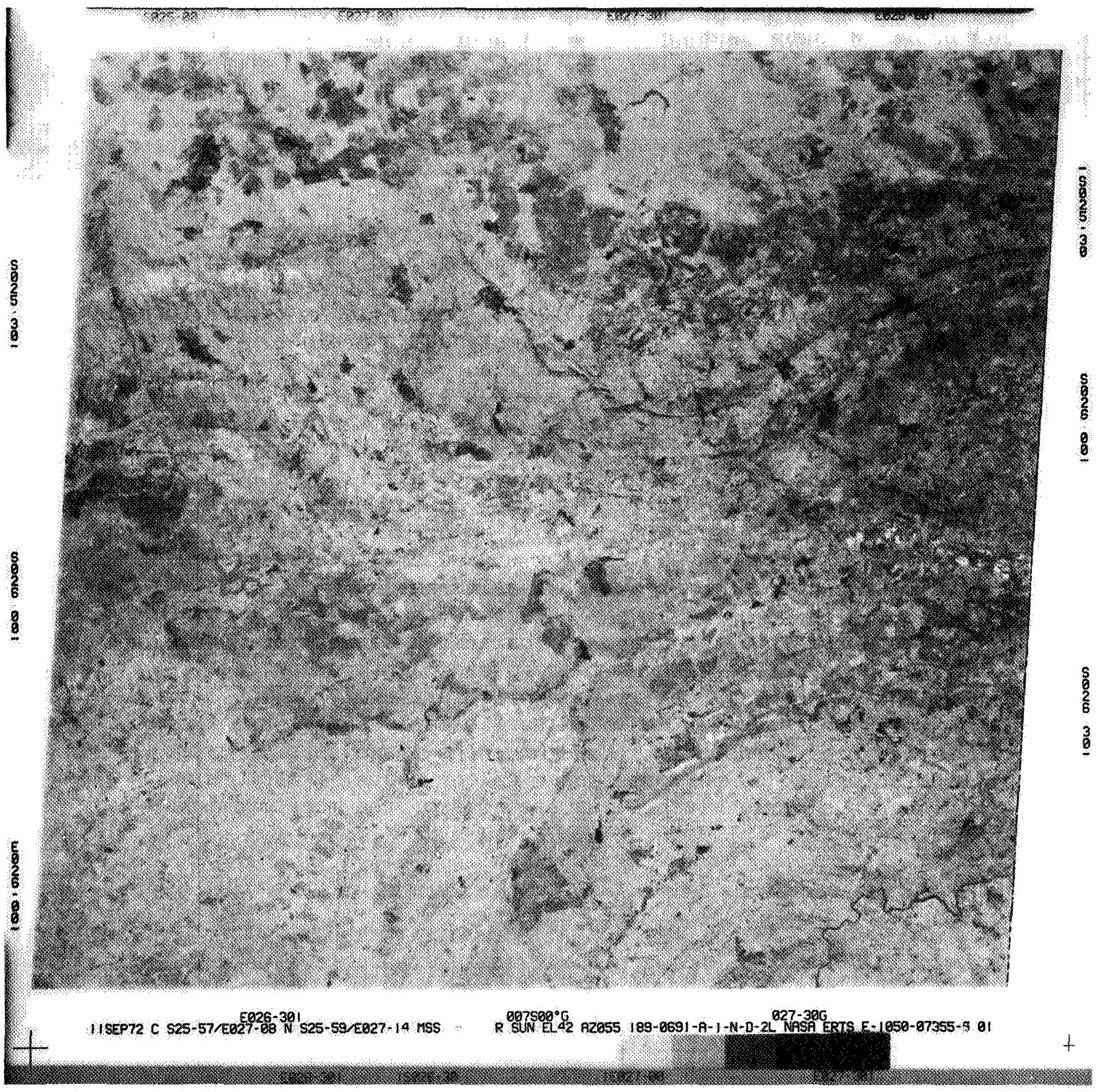

FIG. 2 : Composite colour print of bands 4, 5 and 7 of ERTS-image 1050-07355 gathered on September 11, 1972 at end of dry Winter season.

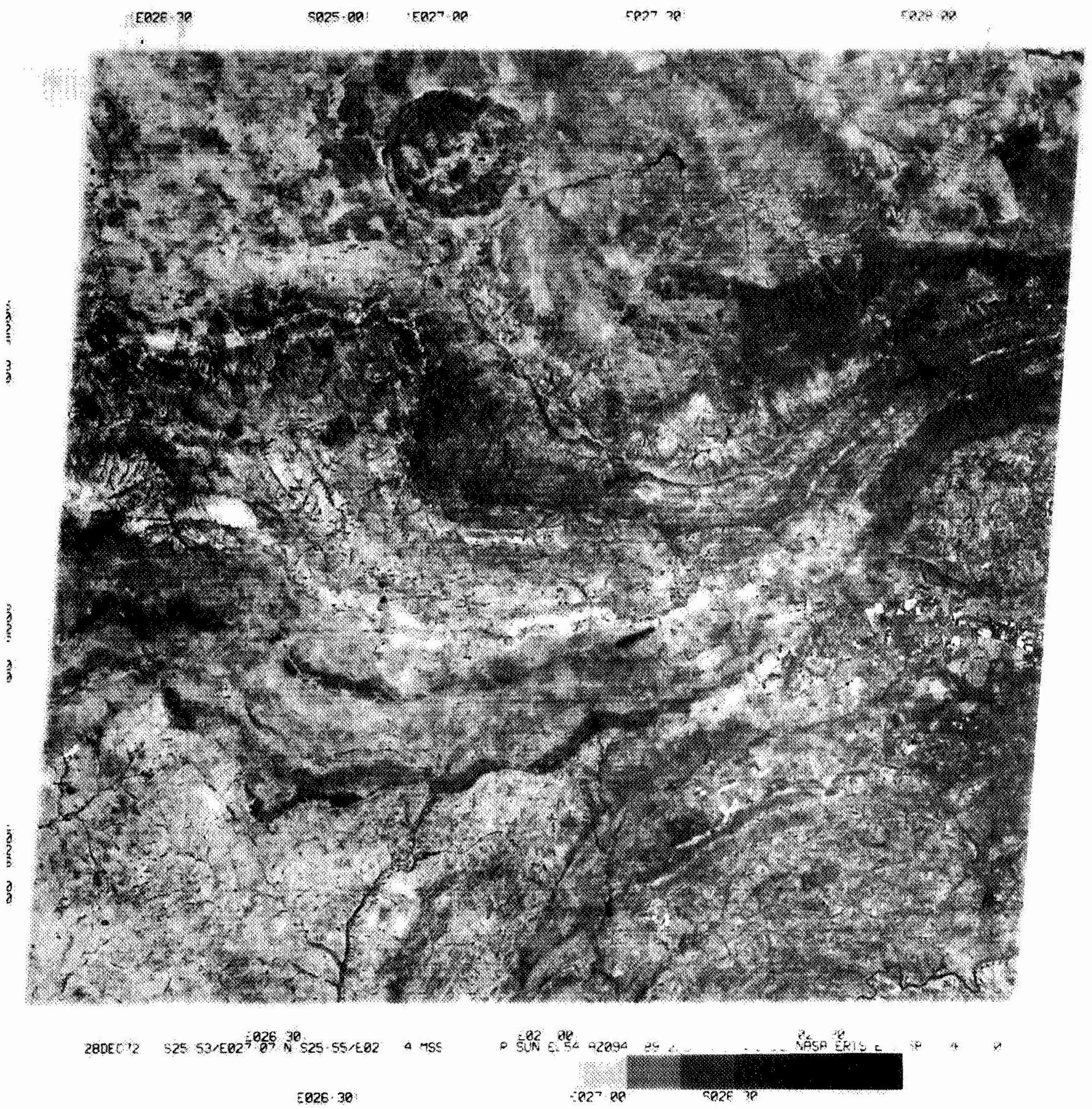

FIG. 3 : Composite colour print of bands 4, 5 and 7 of ERTS-image 1158-07363 gathered on December 28, 1972 during rainy Summer season.

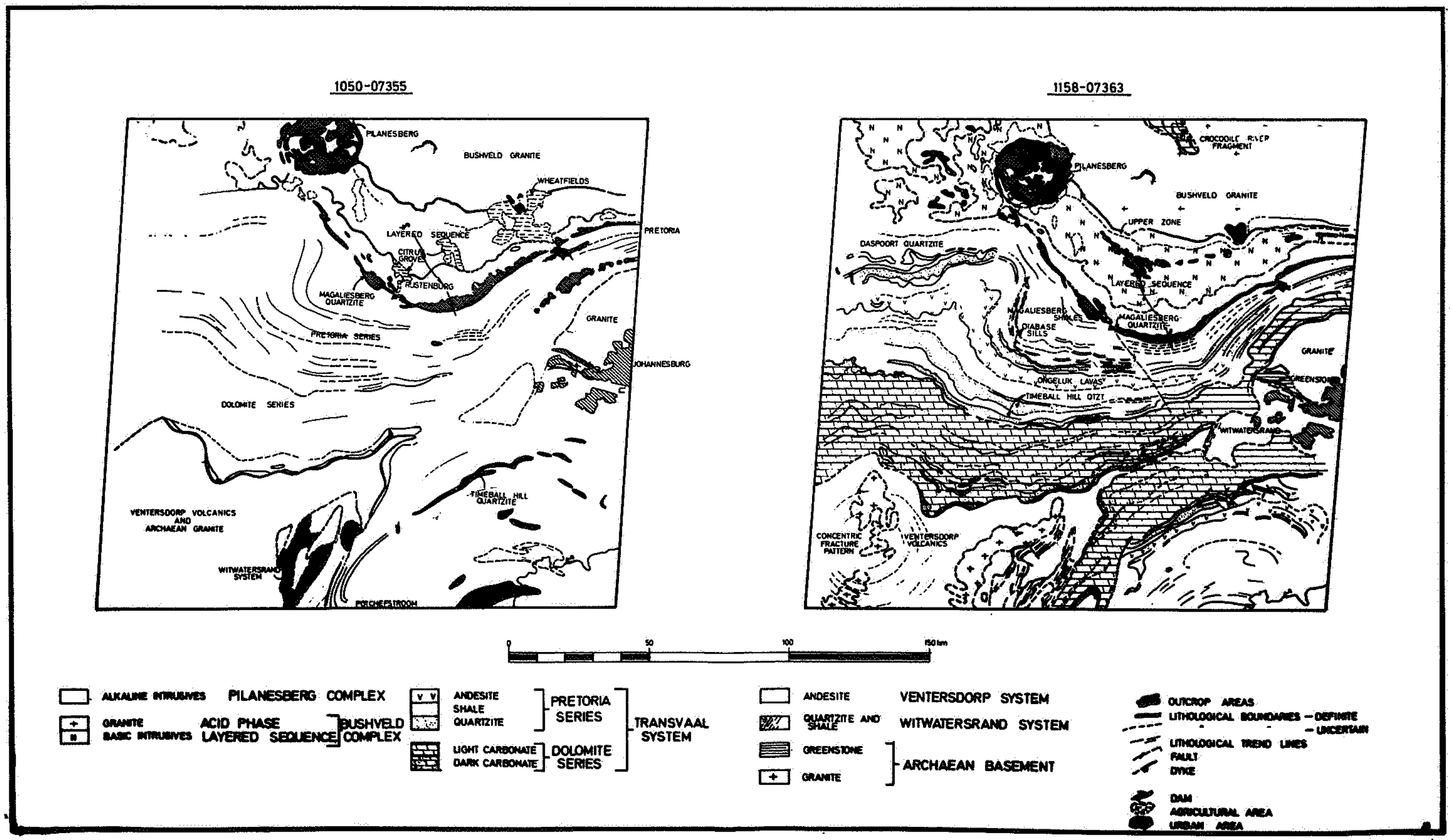

FIG. 4 : Geological interpretation of ERTS-images 1050-07355 and 1158-07363 with emphasis on Lithological Features.

with greenstones can be distinguished only with difficulty. Darker colour tones are also associated with the Witwatersrand Quartzites, though generally these rocks are more readily distinguished on the basis of their distinct linear texture. The Ventersdorp rocks in the south western corner of the image are characterized by a uniform, textureless, green colour tone. The area is one of very poor outcrop but it is nevertheless possible to recognize areas underlain by granite, these exhibiting a yellow colour tone.

Strong tonal variations permit identification and accurate delineation of detailed lithological units in the Transvaal System. Within the Pretoria Series, all significant lithological units can be recognized, with detail in the central portion of the image being comparable with that shown on the official published 1:125 000 map of the area. Quartzite units have an intermediate grey colour tone, (fig. 4), the interbedded shales exhibit a very light colour tone, and the Ongeluk volcanics are locally clearly distinguishable by their green colour tone. The shales of the Magaliesberg Stage exhibit a variable colour tone ranging from light-, to dark-brown, and this may be due to the presence of diabase sills, some of which can be distinguished individually. A few lithological units not shown on the published geological maps can be identified including thin discontinuous shale units immediately above the upper Daspoort Quartzite and lithostratigraphic detail within the Magaliesberg shales. The Transvaal Dolomite is characterized by broad alternating zones of light green and dark grey colour tones. These clearly reflect broad stratigraphic units which to date had not been recognized from this area in spite of the long history of geological activity. Field investigations (Grootenboer, Eriksson and Truswell, 1973) identified the zones as corresponding to units of chert-rich light-coloured and chert-poor dark-coloured dolomitic limestone which could be correlated with the detailed stratigraphy established elsewhere. Certain areas within the Transvaal Dolomite show a distinct uniform green colour tone. Stratigraphic detail is absent in these areas and they almost certainly correspond to local thick soil cover, much of which may be of a transported nature.

Basic rocks of the Bushveld Complex show a distinctive dark-blue colour tone, resulting from their low reflectance in band 7. Areas of outcrop within the Layered Sequence are clearly identifiable. The basal contact of the Sequence is invariably obscured by surficial scree, but the upper contact with the Bushveld Granite is clearly defined and can be accurately traced. Of particular interest is the recognition of a distinct zone of darker tone at the top of the Layered Sequence coinciding with the so-called "Upper Zone", a unit of relatively more magnetite rich gabbroic rocks. To the west of the Pilansberg the numerous small occurrences of quartzite, with associated scree, penetrating the basic rocks of the Complex, are clearly visible. Whilst the granitic rocks of the B.I.C. as a whole are readily recognizable, a more detailed subdivision into granite, granophyre and felsite is not possible. Interpretation is rendered difficult by variable land use patterns, surficial deposits and the effects of donga erosion. A small folded outlier of Transvaal rocks (Crocodile River Fragment) within the Bushveld granite is recognizable only on the basis of its textural characteristics.

Additional features of geological interest which are clearly recognizable on the image include dykes, lineaments, joints, faults, concentric ring structures (all characterized by distinctive textural patterns), areas of scree cover and surficial deposits. Outcrop areas are characterized by a relatively uniform dark-grey colour tone, and their lithologies are frequently indistinguishable on the basis of colour tone alone, in strong contrast with areas of poorer outcrop where strong tonal contrasts reflect the various lithologies. Non-geological features include natural vegetation patterns, agricultural land use patterns, urban areas, dams, streams, rivers, mine dumps, and roads.

DISCUSSION

A comparison of the colour composites of the two images (figs. 2 and 3) reveals striking differences in the tonal contrast between various surface lithologies differences. The depth of colour and tonal contrasts on the December image are enhanced, relative to the September image, permitting recognition of a great amount of geological detail in spite of its technically poor quality. The wealth of tonal variation on the former image does to some degree obscure other geological features such as fracture patterns and areas of outcrop. An examination of the individual spectral bands reveals that the tonal contrasts displayed by the colour composite is present in every individual spectral band. In virtually every instance a particular geological feature is more clearly displayed on a particular band of the December image compared to the same band on the September image. Table 1 provides a summary of the degree to which various geological features are characterized by tonal differences in individual spectral bands and on the colour composites.

A number of factors could be responsible for the differences in tonal contrast between the two images. The uniform tonal enhancement over the whole area of the image and in every individual band strongly suggest that a major large scale seasonal influence is at work. While factors like vegetation, and differential land use could all contribute to the effect, such contributions would generally be confined to individual bands only or to particular areas. It would seem that two factors, both indirectly related to rainfall, are largely responsible for the variation in tonal contrast; viz. soil moisture contrast and atmospheric haze. Fig. 5 illustrates the weekly rainfall for a number of stations in the western Transvaal as well as the dates on which the images were gathered. Over the 4 month period preceding the September image the total precipitation did not exceed 20 mm at any one of the stations. The December image on the other hand was gathered in the middle of the rainy season with weekly precipitation reaching up to 60 mm.

Table I

TONAL CHARACTERIZATION AND RECOGNIZABILITY OF GEOLOGICAL FEATURES IN VARIOUS SPECTRAL BANDS

	Colour Composite		Band 4		Band 5		Band 6		Band 7	
	1050-07355	1158-07363	1050-07355	1158-07363	1050-07355	1158-07363	1050-07355	1158-07363	1050-07363	1158-07363
NASA rating of image quality			G	P	G	P	G	P	G	P
Topographical detail	Distinct	Distinct	v. Poor	Fair	Fair	v. Dist.	Distinct	Fair	Fair	Fair
General Geological Features										
Overal) tone contrast of lithological units	Poor	v.Distinct	v.Poor	Fair	Poor	v.Distinct	Poor	v.Distinct	Poor	v.Distinct
Outcrop areas	Distinct	Poor	v.Poor	Fair	Fair	Distinct	Poor	Poor	Distinct	Poor
Fractures	Fair	Fair		Fair	Distinct	Distinct	Poor	Fair	Fair	Poor
Faults	v.Poor	Distinct		Fair		Distinct		Fair		Fair
Dykes	Distinct	Distinct		Distinct	Poor	Fair		v.Poor	Poor	Poor
Individual Lithologies										
Bushveld: Granite	Fair	Distinct	v.Poor	Distinct	Fair	Fair	Poor	Distinct	Poor	Distinct
Basic Rocks	Distinct	v.Distinct	Poor	Fair	Distinct	Poor	Distinct	v.Distinct	Distinct	v.Distinct
Upper Zone		v.Distinct		v.Distinct		Fair				Poor
Surficial Deposits	Distinct	Distinct	Poor	Distinct	Distinct	Distinct	Distinct	v.Distinct	Fair	v.Distinct
Outcrop Areas	v.Poor	Distinct		Distinct		Distinct	v.Poor	Poor	Poor	Poor
Pilanesberg Complex	Distinct	v.Distinct	Poor(T)	Distinct	Poor(T)	v.Distinct	Poor(T)	Distinct	Poor(T)	Distinct
Pretoria Series: Quartzites		Distinct		Poor		Distinct	v.Poor	Fair		Fair
Shales	Poor	v.Distinct	Poor	Distinct	Poor	v.Distinct	Fair	v.Distinct	Poor	v.Distinct
Volcanics		Distinct		Poor				Distinct		Distinct
Diabase		Fair				Poor		Fair		Distinct
Scree	Poor	Distinct		Poor	Poor	Distinct	Distinct	Distinct	Fair	v.Distinct
Outcrop Areas	v.Distinct	Fair	Poor	Fair	Fair	Distinct	Distinct	Distinct	Distinct	Distinct
Dolomite Series:	Poor	v.Distinct	Poor	Fair	Poor	Fair	Fair	Poor	Poor	Fair
Chert-rich zones		Distinct		Fair		Fair	Fair	Poor		Fair
Chert-poor zones	v.Poor	v.Distinct		Fair		Distinct	v.Poor	v.Distinct		v.Distinct
Outcrop Areas	v.Distinct	Poor			Fair	Fair	v.Distinct	Fair	Distinct	Distinct(T)
Thick Soil		Distinct		Fair		Fair		Poor		Poor
Dykes		Poor						v.Poor		v.Poor
Pre-Transvaal: Granite in east	Poor	v.Distinct	Poor	Distinct	v.Poor	Fair		Poor	v.Poor	Distinct
Granite in southwest	Poor	Distinct	Distinct	Distinct	v.Poor				v.Poor	
Ventersdorp volcanics	Fair	Distinct	Poor	Distinct	Fair	Distinct	Poor	Poor	v.Poor	Fair
Witwatersrand quartz.	Fair(T)	v.Dist.(T)	Poor(T)	Fair(T)	v.Poor(T)	Distinct	v.Poor	Fair		Distinct(T)
Greenstones		v.Poor						Poor		Fair

Note: (T) indicates distinctive textural pattern influencing recognizability.

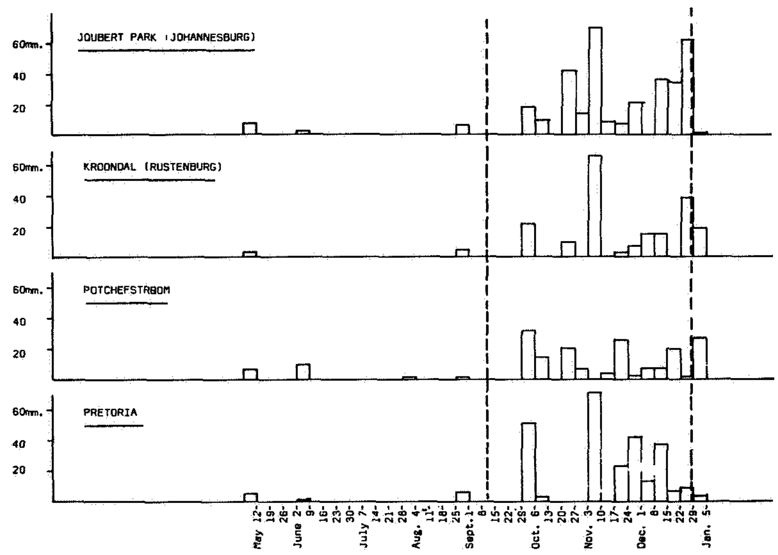

FIG. 5 : Weekly rainfall figures for several towns in the western Transvaal for the period May, 1972 to January, 1973.

During the dry winter months atmospheric haze occurs over most of South Africa, with windblown dust being the main constituent. Such material produces significant back reflection of sunlight and also scatters much of the radiation reflected from ground objects. Both effects result in reduced contrast in ground scenes. During the summer months most of the dust is removed by rainfall, thus producing a clear atmosphere and good contrast.

The effect of soil moisture content is important inter alia in so far as it affects the texture of the reflecting surface of a ground object. Dry soil will approximate a matt surface which may result in significant spectrally non-selective reflection from the top surface. A wet soil (or a soil which has been wet but not disturbed) will presumably exhibit greater spectrally selective absorption.

SUMMARY

1. Two sequential ERTS images of a portion of the western Transvaal Province gathered during the dry winter and rainy summer seasons were compared to investigate the value of repetitive ERTS imagery in geological studies.

2. A detailed comparison was based on colour composite prints of bands 4, 5 and 7, but this was followed by examination of all four individual bands for the two images.

3. The winter image proved to be of low tonal contrast and lithological detail, roughly comparable to that shown on a 1:1 000 000 scale map could be recognized. Fracture patterns and areas of outcrop are readily evident.

4. The summer image (in spite of a NASA rating of "P" for all four bands) shows very marked tonal contrast related to surface lithologies, locally permitting recognition of lithological detail comparable to that indicated on 1:250 000 maps of the area. The intensity of these tonal variations tends to obscure other geological features.

5. The summer image reveals new lithological information particularly in the Transvaal Dolomite where major stratigraphic units are clearly evident. In spite of 90 years of continuous geological activity in the western Transvaal, no such stratigraphic subdivisions had ever been recognized.

6. The enhancement of tonal contrast is evident in every single band of the December image. A comparison of all bands of both images indicates that virtually every single band of each image may display particular geological features to a greater degree than any other.

7. Atmospheric haze and soil moisture content appear to constitute the most important factors in enhancing the tonal contrast of the December image. Both these factors are directly related to rainfall.

8. The investigation clearly indicates the importance of repetitive coverage in the enhancement of particular geological features, in an area of strong seasonal changes.

REFERENCES

Grootenboer, J., Eriksson, K., and Truswell, J., 1973. Stratigraphic Subdivision of the Transvaal Dolomite from ERTS Imagery : ERTS Investigation Symposium, Dec. 10-14, Goddard Space Flight Center.